Assessment of Existing Structures in the Absence of Drawings

by

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WDP

Motivation

- We have a need to evaluate existing structures
  - Prior to rehabilitation
  - Changes in occupancy
  - Sustainability compared to new construction
- Drawings are commonly not available
  - Lost over time
  - Changes in ownership

Goals

- As-built drawings
  - Existing geometry
  - Structure type
- Current conditions
  - Deterioration
  - Variations from original construction
- Material properties
- Clear path forward
  - Analysis / building codes

Issues

- Structural assessment
  - Current conditions
  - Member geometry
  - Material properties
    - $P = [K] \Delta$
    - $\Phi M_n = \Phi As fy (d-a/2) = \Phi 0.85 f'c a b (d-a/2)$
- Analysis requirements / limitations
- Building code requirements

Structural Assessment

- Need to understand "in-situ" conditions
  - Actual geometry – d, b, l
  - Geometry variations
  - Material strength – f'_c and f_y
  - Deterioration / loss of strength

Typical Conditions to Verify

- Verification / identification of member sizes
- Location and spacing of embedded items
  - Mild reinforcing steel, post-tensioning, conduit
  - Masonry ties and hardware
- Locating hidden flaws and defects (voids, trapped moisture, poor consolidation, etc.)
- Corrosion damage assessment
- Concrete properties
- Reinforcing steel properties

Current Geometry

- Measurement
  - Direct measurement
  - Laser scanning
- NDT Methods
  - SPR
  - Impact-echo
  - Infrared thermography
  - Acoustic emission (sounding)
  - Pachometer / eddy current device
  - Electro-chemical corrosion testing

NDT Advantages

- Access to hidden items – “see through walls”
- Better investigations with NDT
- Rapid accumulation of data
- Generally less expensive than destructive testing
- Minimize interruption of building services
- Evaluation and quality assurance

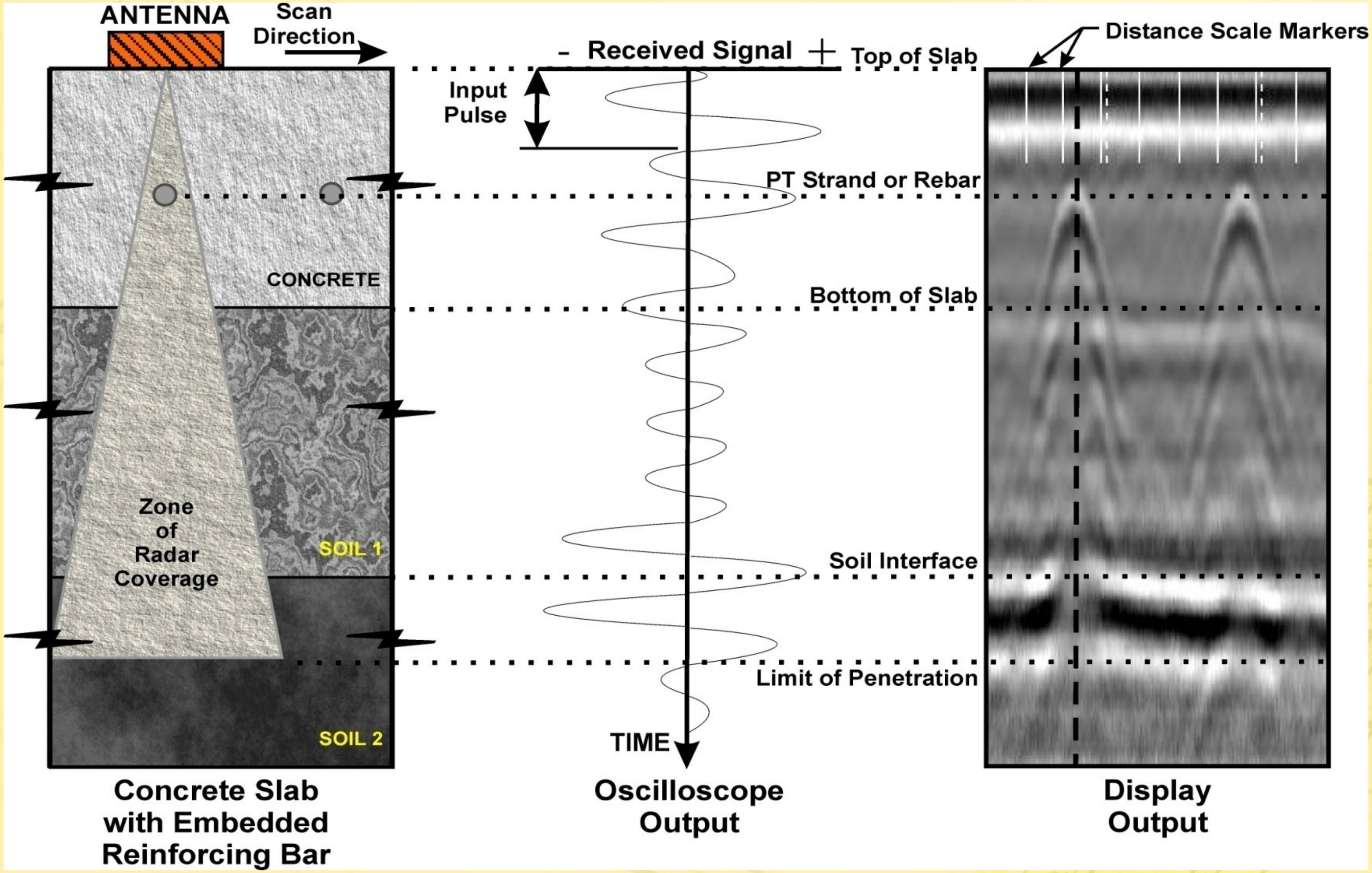
NDT Disadvantages

- More than one test method may be required
- Environmental conditions may effect or distort results
- Construction details & building components may effect results
- Some conditions cannot be determined with a reasonable degree of accuracy without destructive testing

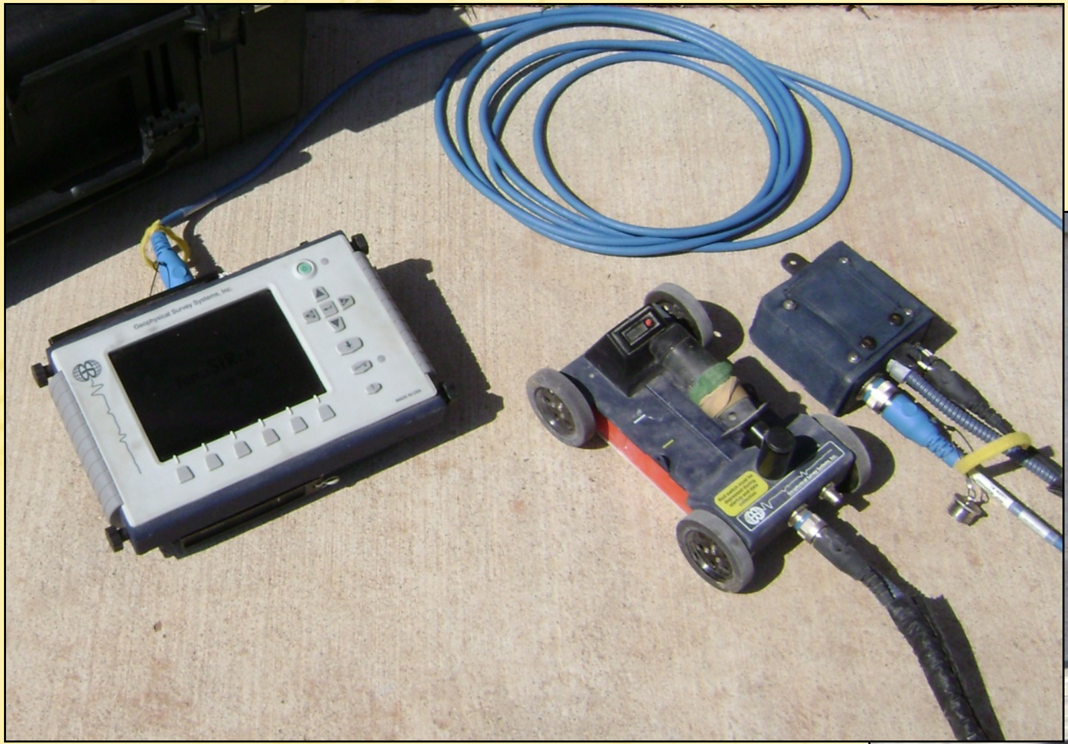
Surface Penetrating Radar

- Uses electromagnetic energy to locate objects, subsurface flaws, or interfaces within a material
  - Thickness determination
  - Location/Orientation/Depth of reinforcement or conduit
  - Track post-tensioning tendon trajectories

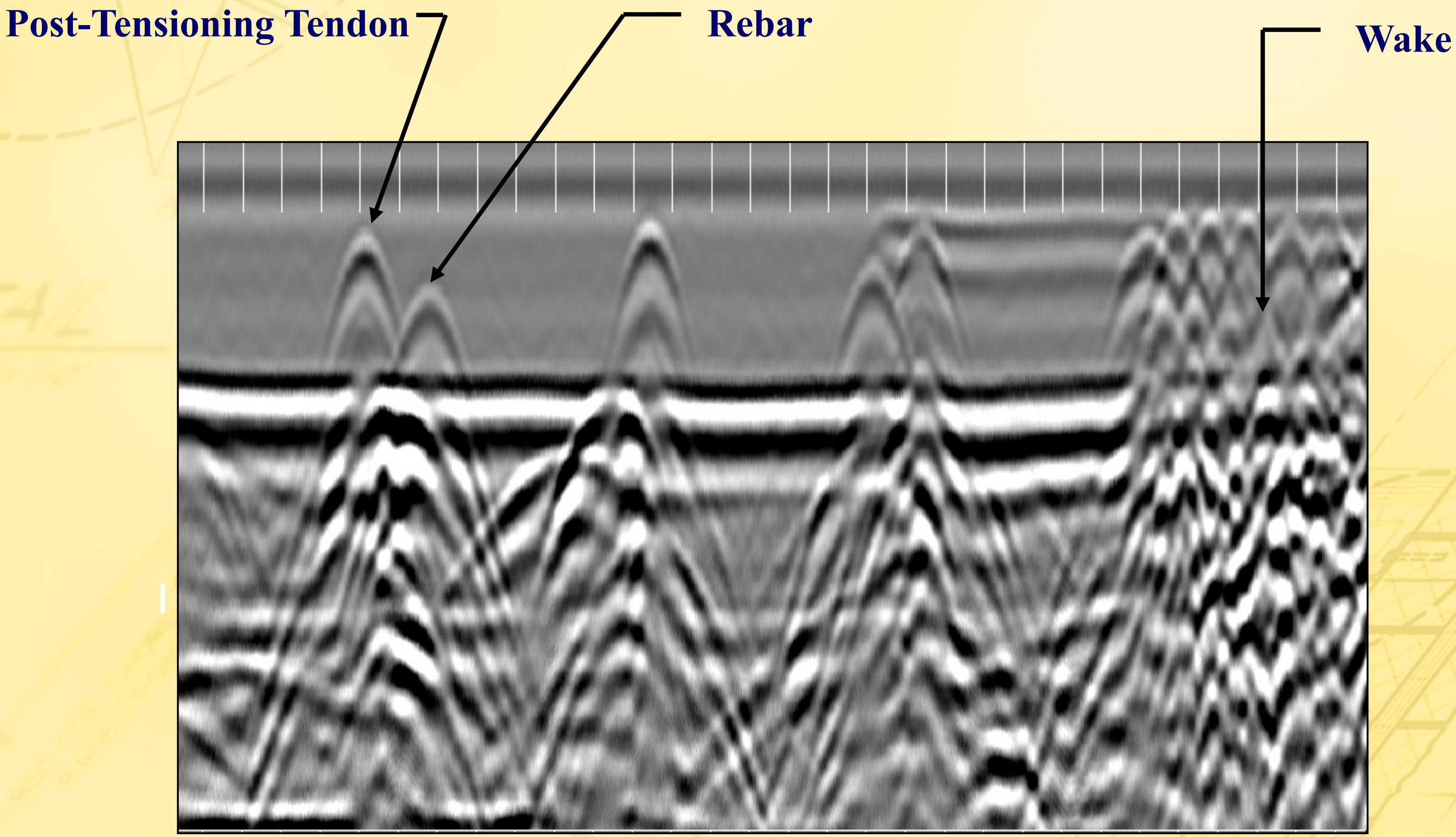
Surface Penetrating Radar



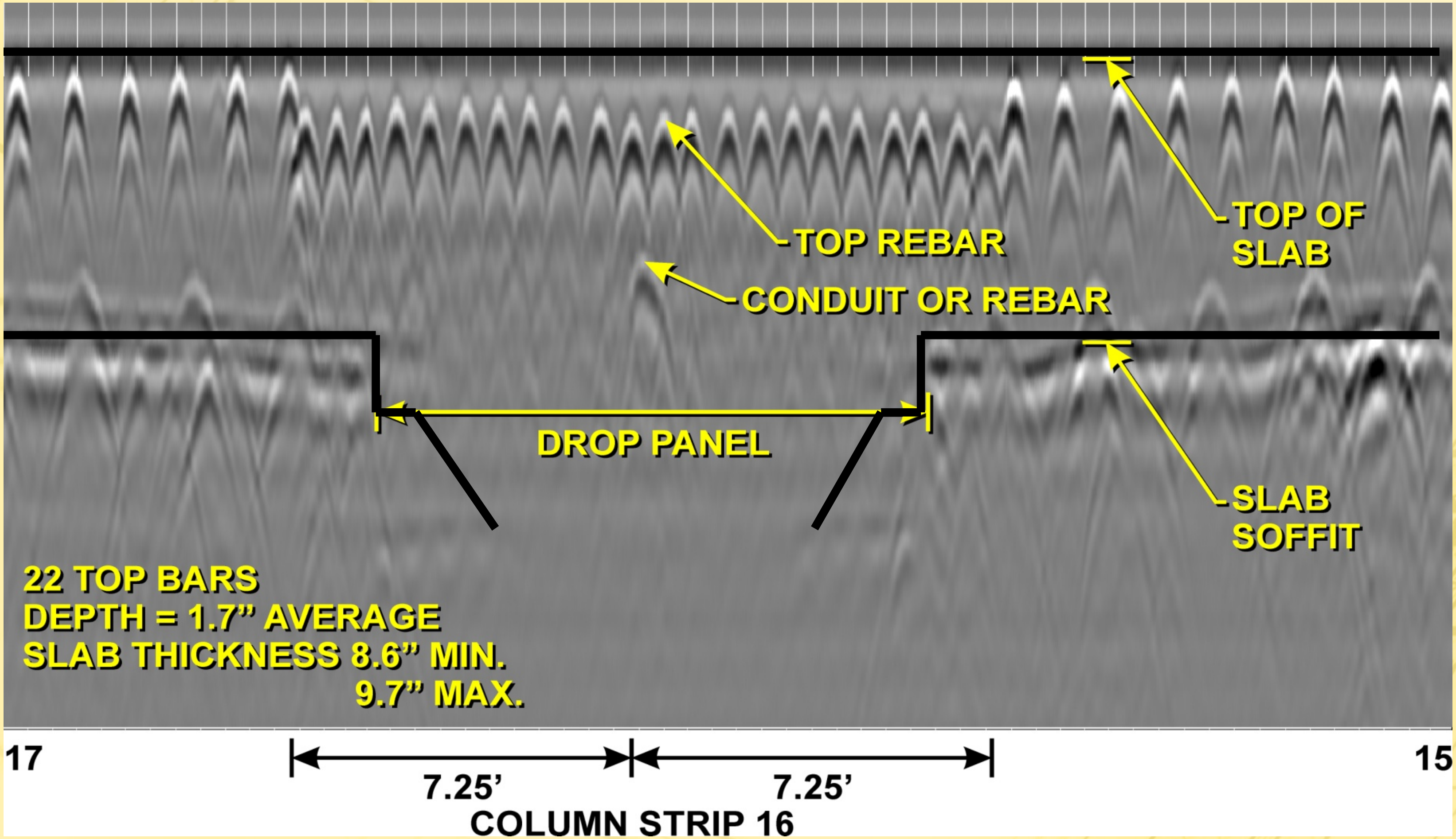
Surface Penetrating Radar



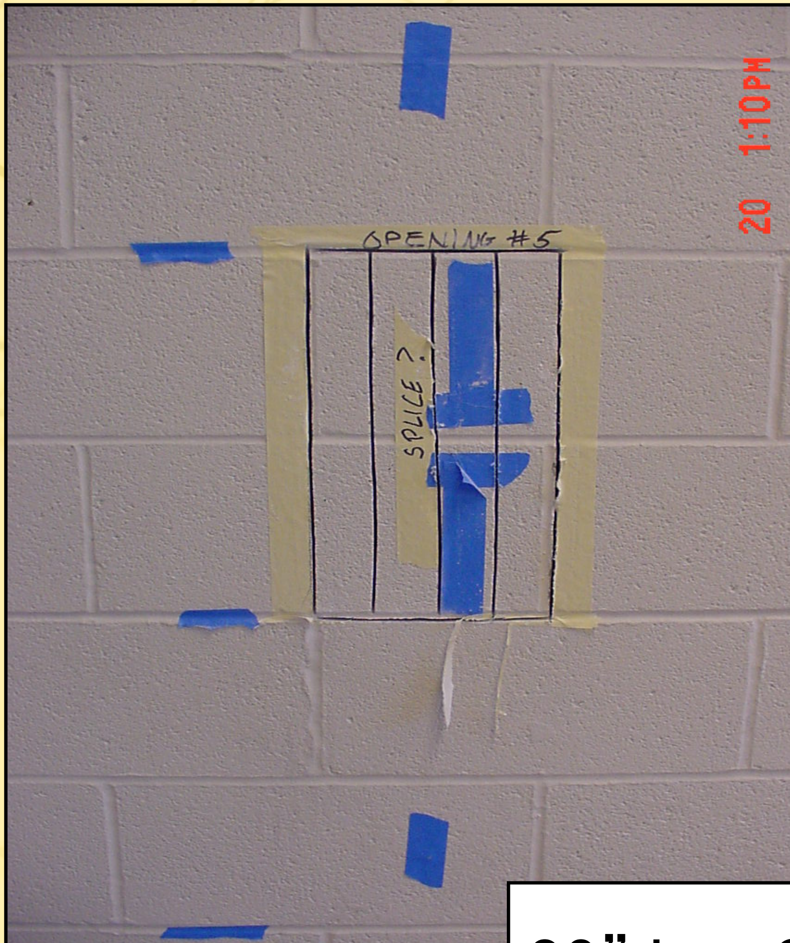
Surface Penetrating Radar



SPR – Parking Structure



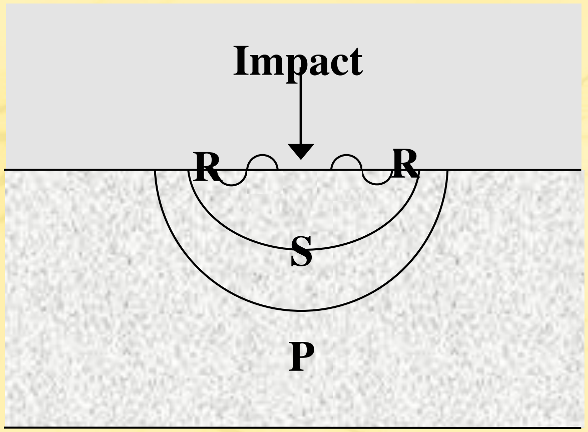
Reinforcement Location



30” Lap Slice Required

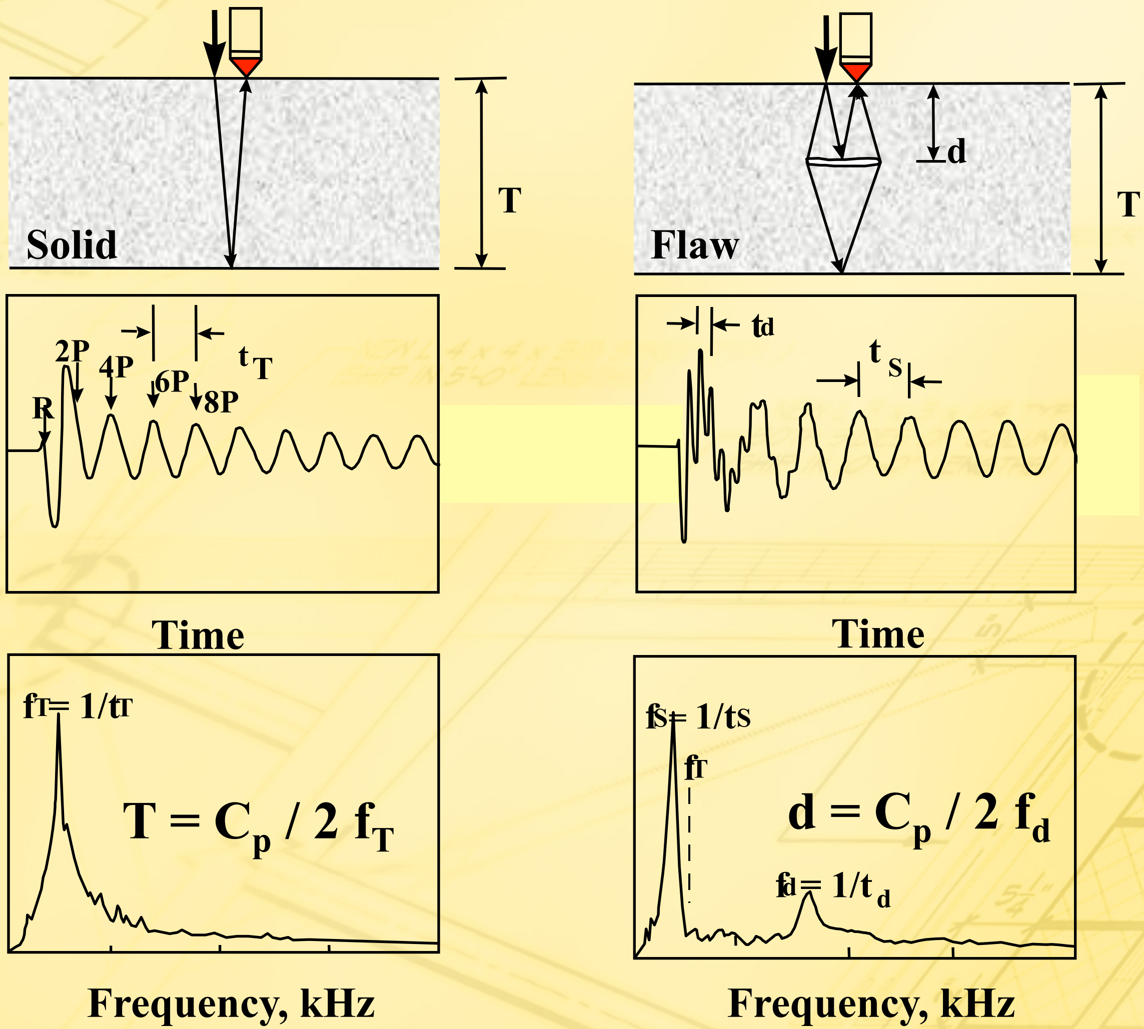
Impact-Echo

- Based upon evaluation of stress waves generated by an elastic impact on a concrete surface
- Originally developed at Cornell University and NIST by M. Sansalone and N. Carino



P – Compression waves
S - Shear waves
R - Rayleigh waves

Impact-Echo



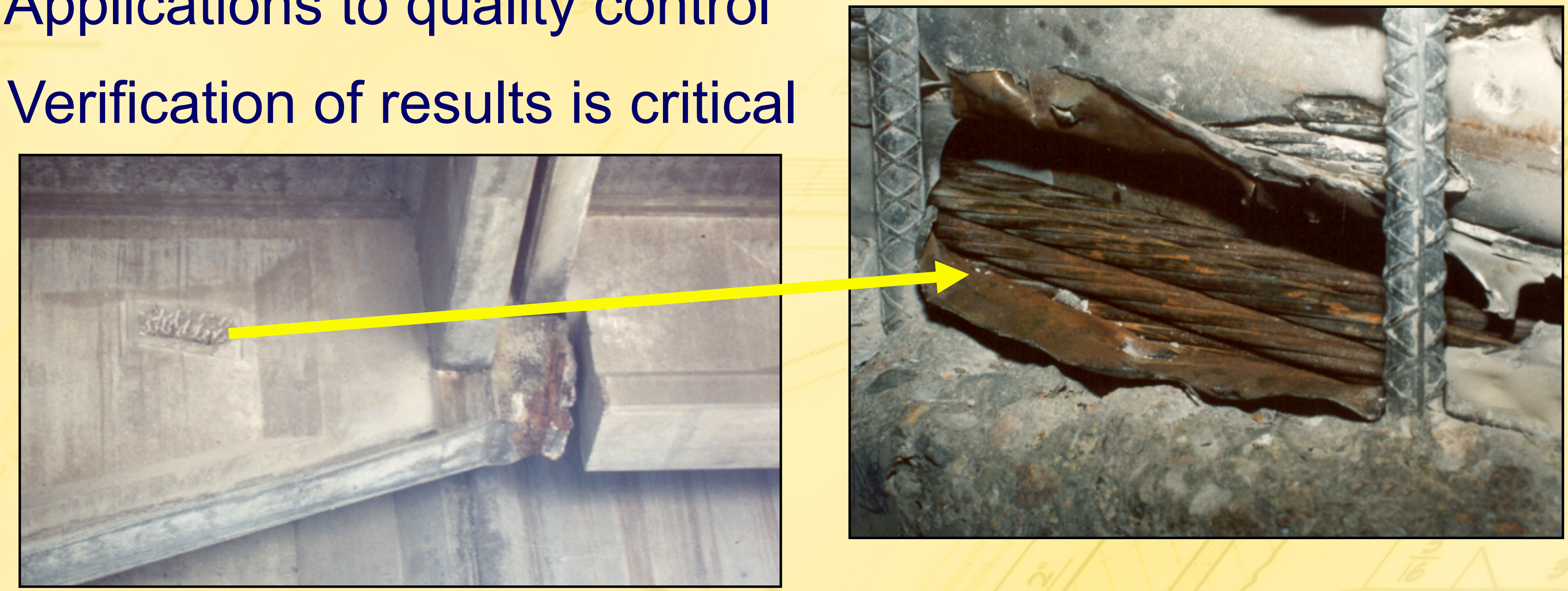
Solid
T
Flaw
d
T
R
2P
4P
6P
8P
tT
td
ts
Time
Time
fT = 1/tT
T = Cp / 2 fT
Frequency, kHz
fs = 1/ts
fT
d = Cp / 2 fd
fd = 1/td
Frequency, kHz

Impact-Echo

- Applications
  - Thickness of members – d,b
    - ASTM C1383
  - Location of internal defects
    - Voids / delaminations
  - Repair quality assurance
  - Internal damage
    - ASR / DEF / ACR

Impact-Echo

- Summary
  - Requires significant experience
  - Powerful method for flaw detection
  - Applications to quality control
  - Verification of results is critical



Issues

- Structural assessment
  - Current conditions
  - Member geometry
  - Material properties
- Analysis requirements / limitations
- Building code requirements

Material Properties

- Information Sources
  - Historical material properties
    - ASCE 41
    - CRSI References
  - Construction documents
  - Construction testing records
  - In-situ testing

Material Properties

- Concrete
  - Compressive strength
  - Durability
    - Air content
- Reinforcing steel
  - Yield strength
  - Ductility
  - Corrosion damage

Concrete Strength

- Testing of core samples
  - ACI 214.4
  - Corrections for sample conditions
  - Number of samples
- Estimation from in-direct methods
  - Summarized in ACI 228.1R
  - Requires correlation with core test results
  - In-direct in nature

Core Testing

- "Equivalent specified strength"
  - f' c not fc (core strength)
  - ACI 318
    - 10% fractile strength
- Corrections
  - Length, curing, size, etc
- Number of samples
  - Representative of structure
    - Different strength in beams / columns
  - Understand acceptable level of variability

Core Testing

- ACI 318 vs Existing Structures
  - Section 5.6.5.4
  - Low strength concrete investigation
  - Core strength of 0.85 f’ c is adequate
- Not appropriate for existing structures
  - Provision is for new structures only
  - 0.85 f’ c = 0.85 f’ c
  - Chapter 20 – 2008 code

Core Testing

- Number of samples
  - ASTM E 122
    - $n = (2 V / e)^2$
    - V = estimate coefficient of population variation
    - e = maximum error allowable
  - ASTM E 178
    - Eliminate outliers
    - Skew results
  - Sufficient number to assess population
    - ASCE 41 / ACI 562

Core Testing

- "Equivalent specified strength"
  - Convert corrected core strength into f' c
  - Tolerance factor approach
  - Canadian Bridge Code / ACI 562
    - $$f_c' = 0.9\bar{f}_c\left[1-1.28\sqrt{{(k_cV)^2}/{n}+0.0015}\right]$$
    - n – number of samples
    - V – variance
    - k_c – constant based upon number of samples

Estimation of Concrete Strength

- ACI 228.1
- Test methods – require correlation with cores
  - Probe / Pin penetration – ASTM C 803
  - Pull out tests – ASTM C 900
  - Pulse velocity – ASTM C 597
  - Rebound hammer – ASTM C 805
- Faster than core testing
  - More samples can be tested
  - Identify low strength areas

Estimation of Concrete Strength

- "Windsor" probe - ASTM C 803
  - Utilizes a powder charge to drive probes into the concrete with a known force
  - Generally accurate results

Estimation of Concrete Strength

- Pullout test – ASTM C 900
  - Cast in place or post-installed studs
  - Pullout force is tensile strength measure
  - Common in UK for form stripping

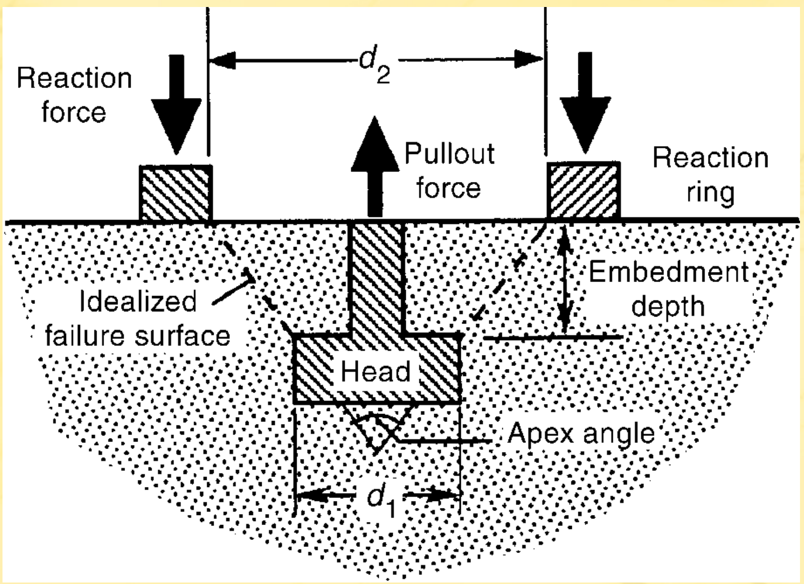


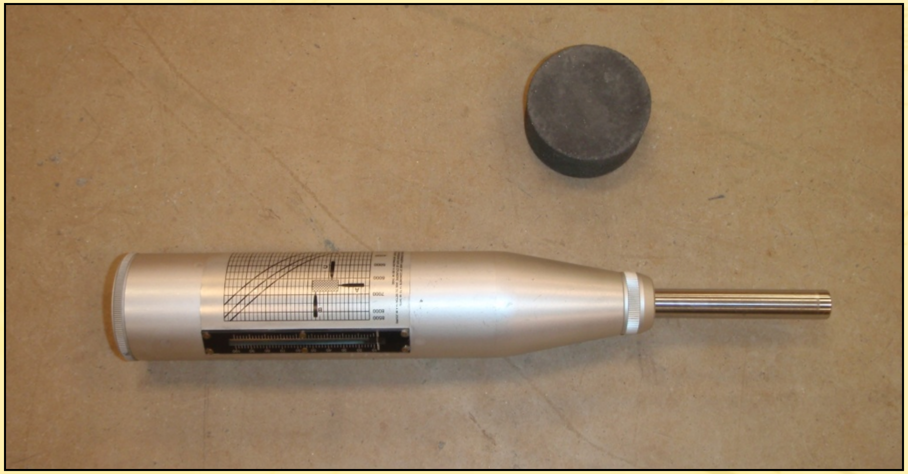
Figure adopted from ACI 228.1R-03

Estimation of Concrete Strength

- Pulse velocity – ASTM C 597
  - Measure travel time of an ultrasonic pulse
  - Correlates to compressive strength
  - NDT tool

Estimation of Concrete Strength

- Rebound Hammer – ASTM C 805
  - Utilizes an internal spring and rod to strike the concrete with a calibrated force
  - Easy to use
  - Variable results



Estimation of Concrete Strength

- Correlation with core tests
  - Two sources of variability from "true strength"
  - In-place test results and core test result
  - Several methods presented in ACI 228.1R

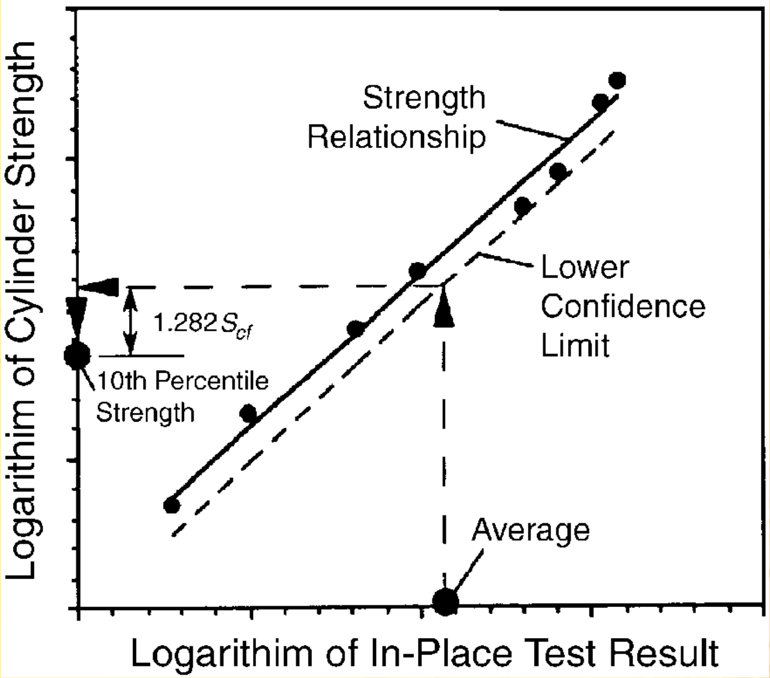
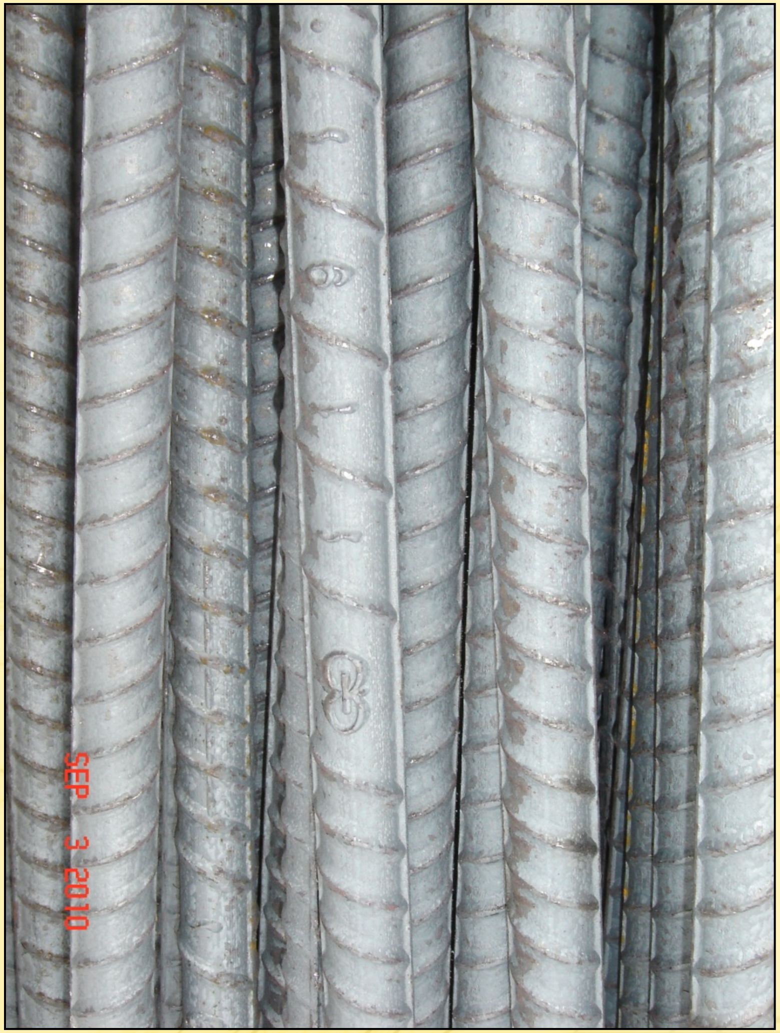


Figure adopted from ACI 228.1R-03

Reinforcing Steel

- Verify yield strength
  - 30 to 40 to 60 to ??ksi
  - Ductility
- NDT Methods
  - Not possible
- Grade marks
  - Hard to find
- Destructive tests



Existing Structures

- Use of NDT methods
  - Expand tested area
  - Identify low strength areas
  - Verification of previous testing results

Issues

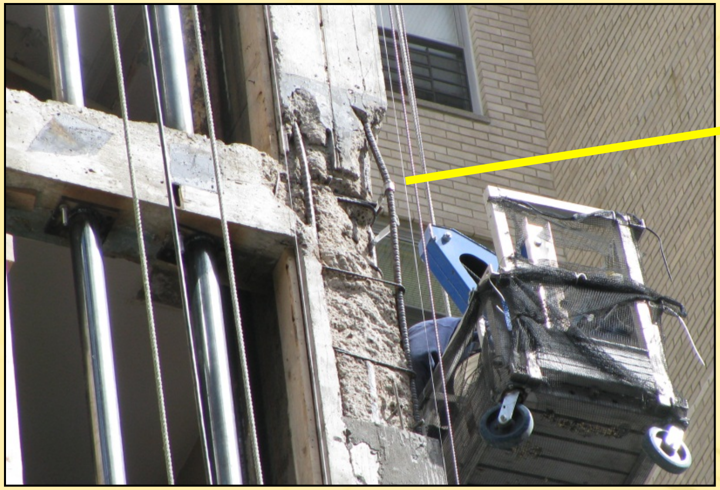
- Structural Assessment
  - Current conditions
  - Member geometry
  - Material properties
- Analysis Requirements / Limitations
- Building Code Requirements

Analysis Issues

- Capacity of Existing Structure
  - Account for in-situ conditions
  - Account for actual material properties
  - Account for construction process
- Design for "future" loads

Analysis Issues

- Construction process
  - Unbraced length changes
  - Shoring
    - Loads imposed
  - Temporary loads



Load Testing

- Valid method to assess existing structures
- Supplement analysis results
- ACI 437
  - Load magnitude
  - Duration
  - Standard in development

Building Code Issues

- Project specific assessment
- When do current code requirements have to be satisfied?
  - Grandfather clause?
  - Seismic requirements?
  - Energy codes?
- IBC Codes
  - Chapter 34 – Existing Structures
  - 5% rule

ACI 562

- Concrete repair code
  - Under development
  - Expect completion in 2012
  - Parallel to ACI 318 for repair
  - Adopt into IEBC or IBC
- Code requirements not guidelines
  - Evaluation
  - Repair design
  - Quality control

Summary

- Existing structures commonly encountered
  - Lack of design / construction documents
  - Need to preserve / protect these structures
- Assessment
  - Numerous methods exist
  - Generally project specific
- Analysis / Codes
  - More involved than new structures

Thank You

QUESTIONS?